Announcements

- Homework for tomorrow…

  Ch. 30 [redacted]: CQ 3, Probs. 4, 6, & 8

  CQ10: a) ΔV_C -> ΔV_C b) C -> $C/2$ c) Q -> $Q/2$

  29.20: (240/79) μF

  29.22: 20 μF in parallel

  29.54: $Q_1 = 4\ \mu$C, $Q_2 = 12\ \mu$C, $Q_3 = 16\ \mu$C, $\Delta V_1 = \Delta V_2 = 1$V, $\Delta V_3 = 8$V

- Office hours…

  MW 10-11 am

  TR 9-10 am

  F 12-1 pm

- Tutorial Learning Center (TLC) hours:

  MTWR 8-6 pm

  F 8-11 am, 2-5 pm

  Su 1-5 pm

Chapter 30

Current & Resistance

(*Creating a Current*)

Review…

- *Energy stored in a capacitor…*

$$\boxed{U_C = \frac{Q^2}{2C} = \frac{1}{2}C(\Delta V_C)^2}$$

- *Energy density of a capacitor…*

$$\boxed{u_E = \frac{1}{2}\epsilon_0 E^2}$$

- *Electron current…*

Drift velocity

$$\boxed{i_e = n_e A v_d}$$

e^- number density

cross-sectional area

Quiz Question 1

A wire carries a current. If both the wire diameter and the electron drift speed are *doubled*, the electron current increases by a factor of

$i_e = n_e A v_d$

$v_d \to 2v_d$

$A \to 4A$

$4(2) = 8$

1. 2.
2. 4.
3. 6.
4. 8.
5. Some other value.

i.e. 30.1: The size of the electron current

What is the electron current in a 2.0 mm diameter copper wire if the electron drift speed is 1.0 x 10^{-4} m/s?

Given: n_e=8.5 x 10^{28} m^{-3} for copper.

$i_e = n_e A v_d$

$r = 1.0 \times 10^{-3}\,m$

$v_d = 1.0 \times 10^{-4}\,m/s$

$n_e = 8.5 \times 10^{28}\,m^{-3}$

$A = \pi r^2$

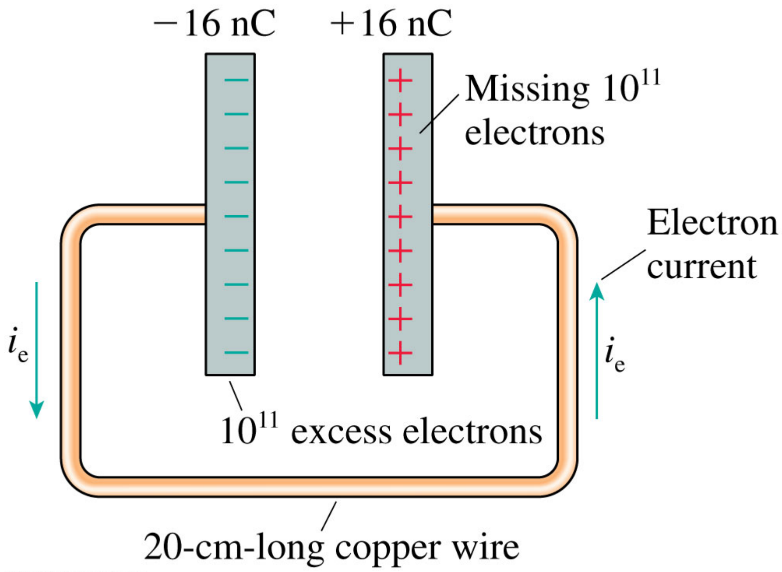
$= \pi (1.0 \times 10^{-3}\,m)^2$

$i_e = (8.5 \times 10^{-28}\,m^{-3})(\pi (1.0 \times 10^{-3}\,m)^2)(1.0 \times 10^{-4}\,m/s)$

$i_e = 2.6 \times 10^{-19}\,s^{-1}$

Discharging a capacitor…

How long does it take to discharge the capacitor?



$R = 1.0\times10^{-3}\,m$
$\ell = 20\times10^{-2}\,m$
$Q = 1.6\times10^{-8}\,C$

Excess electrons on the negative plate?

$Q = 1.6\times10^{-8}\,C$
$q = 1.602\times10^{-19}\,C$

$Q = N_e' q \quad : \quad N_e' = \dfrac{Q}{q}$

$N_e = 1\times10^{11}$ electrons

100,000,000,000 electrons

$A = \pi(1.0\times10^{-3}\,m)^2$
$= \pi(1.0\times10^{-6}\,m)$

How many free electrons in Cu wire

$n_e^- = n_e V = \pi R^2 \ell = 5.3\times10^{22}$

5.3×10^{22} electrons

Length of wire, ℓ', needed to hold the n_e^- electrons

$\dfrac{N_e}{\ell} = \dfrac{N_e'}{\ell'}$

$\ell' = \dfrac{N_e' \ell}{N_e} \approx 4.0\times10^{-13}\,m$

Drift velocity

$V_d = \dfrac{\ell'}{\Delta t} \qquad \Delta t = \dfrac{\ell'}{V_d} = 4.0\times10^{-9}\,s$

30.2:
Creating a Current

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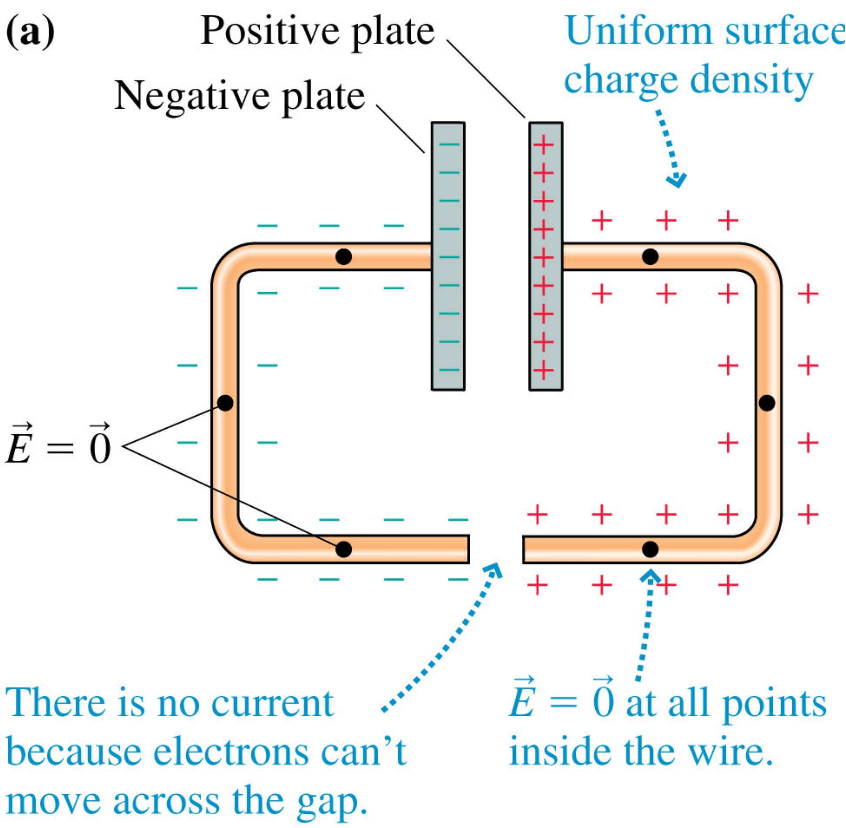
- Q: If there is a *non-zero E*-field, then there is a *non-zero F*, so shouldn't my electrons accelerate?
  - instead of move at a *constant drift velocity*, v_d?

Establishing an *E*-field in a Wire

Notice:

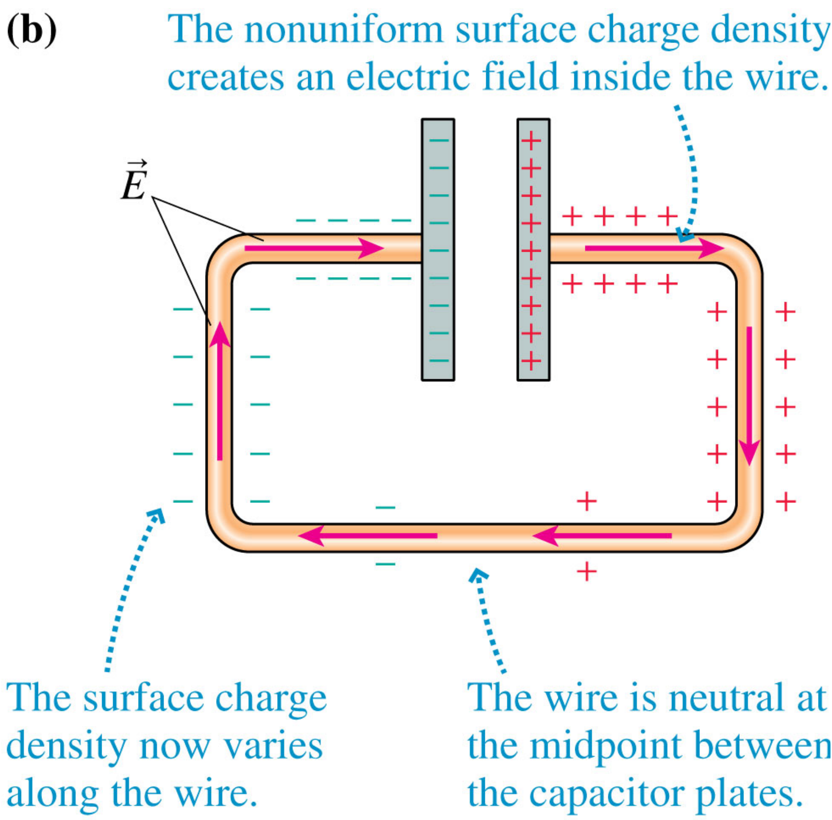
- conductors are in *electrostatic equilibrium*.
- $E = 0$ inside the wire, *all* excess charge resides on the surface.
- *Surface charge density* is uniform.



Establishing an *E*-field in a Wire

Notice:

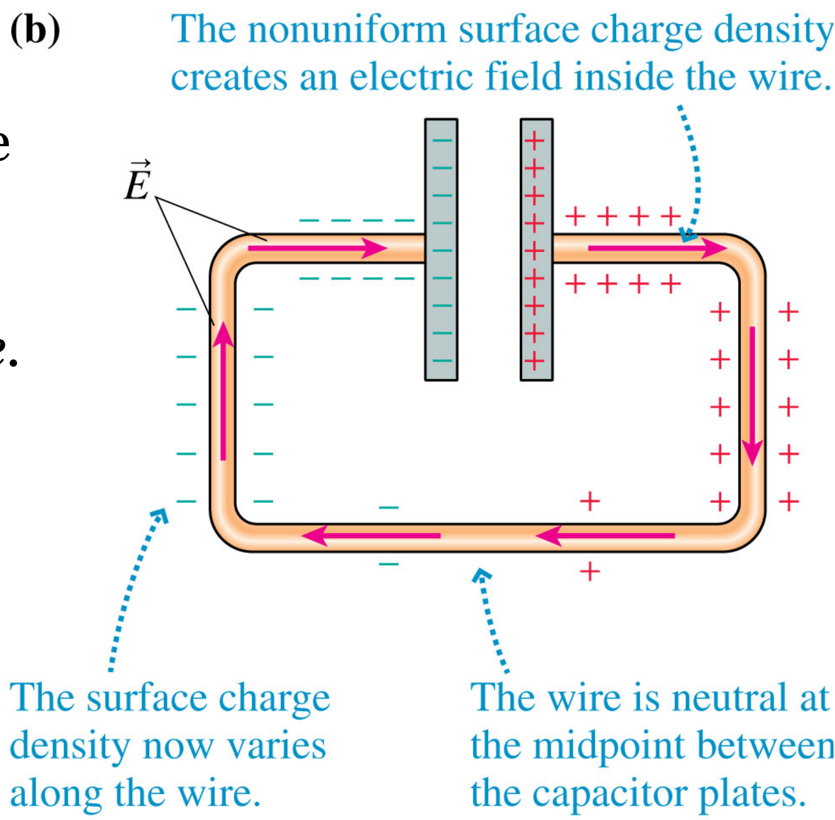
- Within $\Delta t \sim 1$ ns, sea of electrons shift slightly.
- conductors are NOT in *electrostatic equilibrium*.
- *Surface charge density* is no longer uniform.
- *Non-zero E*-field inside the wire.
- *E*-field creates a current.



Establishing an E-field in a Wire

Notice:

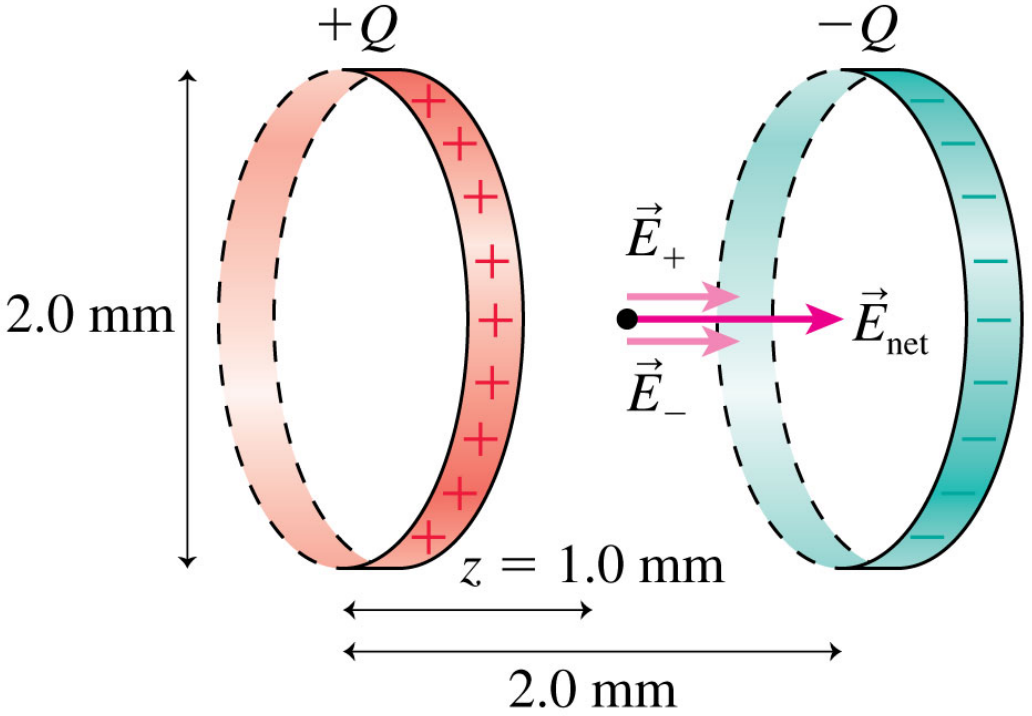
- *Surface charges* are NOT the moving charges.
- i_e (electron current) is *inside* the wire, NOT on the *surface*.



i.e. 30.2: The surface charge on a current-carrying wire

Consider a typical E-field strength of 0.01 V/m. Two 2.0 mm diameter rings are 2.0 mm apart. They are charged to $\pm Q$.

What is Q?



$E_{net} = 0.01$ V/m

$E_+ = 0.005$ V/m $\qquad E_- = 0.005$ V/m

$$E_+ = \frac{KQz}{(z^2+R^2)^{3/2}} \qquad R = 1.0 \times 10^{-3}\ \text{m} \quad z = 1.0 \times 10^{-3}\ \text{m}$$

$$Q = \frac{1}{K} E_+ \frac{(z^2+R^2)^{3/2}}{z} = 1.6 \times 10^{-18}\ \text{C}$$

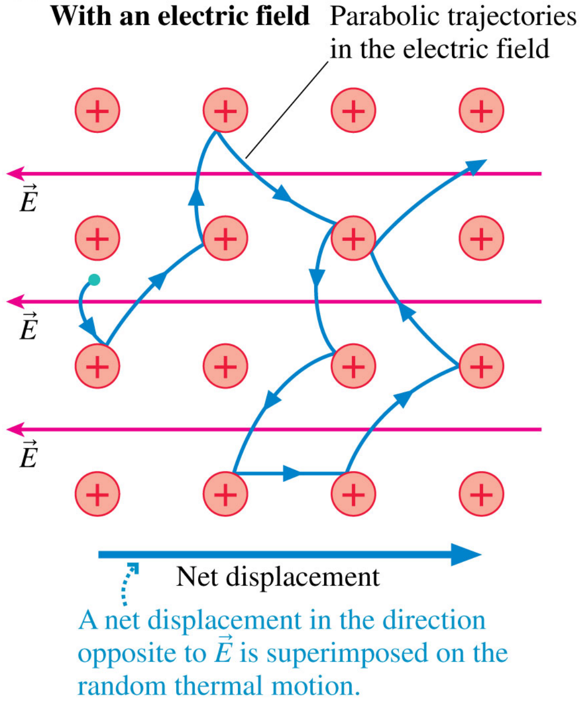
$$N_e = \frac{Q}{q} = \frac{1.6 \times 10^{-18}\ \text{C}}{1.6 \times 10^{-19}\ \text{C}} = 10$$

$N_e = 10$ electrons

A Model of Conduction

Q: If there is a *non-zero E*-field, then there is a *non-zero F*, so shouldn't my electrons accelerate?

- instead of move at a *constant drift velocity*, v_d?



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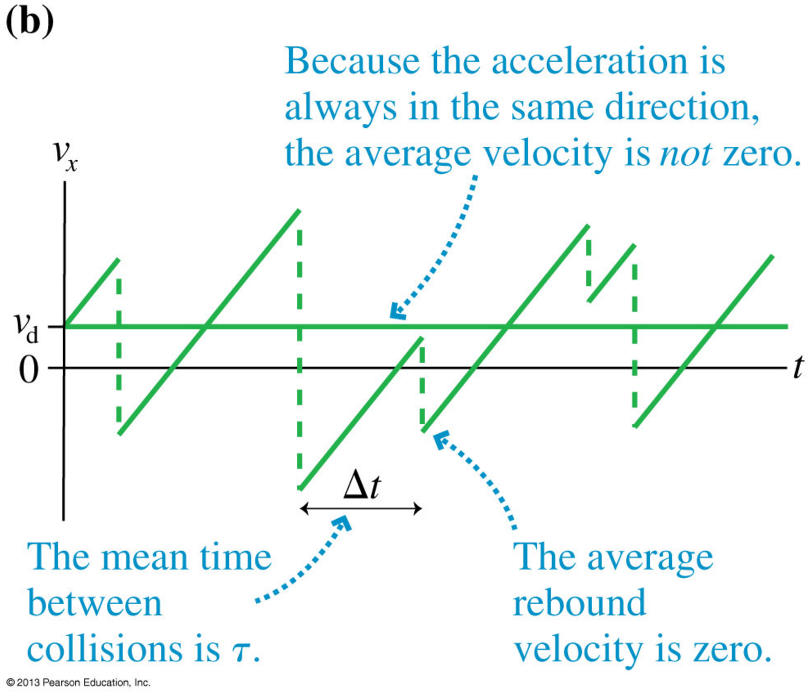

A Model of Conduction

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$$v_d = \frac{e\tau}{m}E$$

so the electron current is..

$$i_e = \frac{n_e e\tau A}{m}E$$

(b)